Project Proposal

The Realtime Hurricane Wind Analysis Project as proposed to the HPCC committee in August of 1998.

A Distributed, Real-time, Hurricane Wind Analysis System

An FY2000 proposal to the NOAA High Performance Computing and Communications Program

Dr. Mark D. Powell
NOAA/ERL/AOML
Hurricane Research Division
R/E/AO1
4301 Rickenbacker Cswy
Miami, FL
33149-1097
powell@aoml.noaa.gov

Philip Schneider, P.E.
NIBS
1090 Vermont Ave. N.W.
Suite 700
Washington D.C.
20005-4905
pshneider@nibs.org

Dr. Edward Rappaport
NOAA/NWS/NCEP
Technical Support Branch
National Hurricane Center
W/NP8
11691 S.W. 17 St
Miami, FL
33165-2149
ed@nhc.noaa.gov

Theme: Crisis / Disaster monitoring or response
FY 2000: $75 K NOAA, $75K National Institute for Building Sciences (NIBS)
*(This proposal is also being submitted to competitive process at NIBS for matching funds)

______________________________ Date:____________
Kristina Katsaros, Director
Atlantic Oceanographic and Meteorological Laboratory
katsaros@aoml.noaa.gov

______________________________ Date:____________
Hugh E. Willoughby, Director
NOAA Hurricane Research Division
Atlantic Oceanographic and Meteorological Laboratory
willoughby@aoml.noaa.gov

---

[1]Principal Investigator
Corresponding Address: NOAA-HRD-AOML
Routing Code: R/E/AO/HRD
4301 Rickenbacker Causeway, Miami FL 33149
Fax: (305) 361-4402
email: powell@aoml.noaa.gov Phone: (305) 361-4403

Executive Summary

Timely information on the actual areas impacted by a hurricane's eyewall and strongest winds at the earliest stages following a disaster should assist emergency managers in allocating recovery resources, detecting potential search and rescue areas, and assessing storm damage before visual inspections are possible. We envision an interactive system which will allow scientific users to select a storm, focus on a particular time in the history of the storm in a graphical manner, examine and quality control the real-time or retrospective data collected during the time period of interest, analyze and archive the wind field, and create a variety of graphical analysis products or data sets derived from the wind field. The system software will be capable of running on a workstation or a web browser to facilitate deployment as a hardware-independent, scientific application. The immediate goal is to create an improved research tool to assist HRD scientists conducting experimental real-time wind analyses at the National Hurricane Center. These analyses are made available as guidance to forecasters at the National Hurricane Center and are helpful for identifying the extent of damaging winds and their distribution. A separate application will allow emergency managment users to select from a menu of products derived from the wind field and formatted to facilitate post-landfall input to GIS/ damage assessment software such as HAZUS from FEMA. A longer term goal will be to make the analysis system application available to NHC staff as a research tool and discuss ways to eventually transfer the technology to operational use.

1. Statement of Problem

Response to a hurricane disaster depends on obtaining accurate and timely information on the magnitude and geographical distribution of the damage caused by the event. This information will determine which communities were most devastated and require immediate attention; it will also assist decision-making associated with the recovery process. Advances in computing and communications have made it possible to obtain tropical cyclone wind observations in near real-time (Burpee, et al., 1994, Griffin, 1992, Powell et al., 1996, 1998). However, scientists involved in hurricane forecasting and research have few tools that enable real-time examination and analysis of these data. Hurricane wind fields are determined subjectively based on the specialist's interpretation of flight-level reconnaissance data, satellite observations, pressure-wind relationships and available surface data. These fields are represented by text portions of the NHC forecast product as radii (from the storm center) of 34 kt, 50 kt, and hurricane force winds in four compass quadrants relative to north. Emergency managers require accurate and fine scale wind field information to input to geographic information systems (GIS) and damage models. Emergency managers have access to only coarse scale information on the wind field through the wind radii information provided in NHC forecasts and advisories, and are considering the use of parametric wind models to provide more detailed wind field coverage. These wind models are no substitute for real data and tend to oversimplify hurricane structure by not adequately accounting for asymmetries in the wind field caused by convection, land-sea friction differences, intensification, and environmental wind shear. Furthermore such models may contradict the operational forecast information which could lead to confusion among emergency managers. Numerical forecast models are initialized from dynamically constrained analyses of some of the same observations mentioned above. However, these fields are not available in real time, do not have the most recent observations due to early cut off times, lack mesoscale detail due to the dynamic constraint, and do not typically contain high resolution information from the reconaissance and research aircraft.

2. NOAA HPCC Program Relevance

This solution is consistent with the goal of NOAA's HPCC program to disseminate real-time and historical information to users more completely, in usable forms, and in a timely manner through the Internet. The analysis system will help to fulfill NOAA's strategic plan objective as research to advance short-term warning and forecast services. This proposal also addresses FEMA's goals to reduce loss of life and property and protect our nation's critical infrastructure from hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery. It is critical for public safety that storm information exchanged between the agencies be consistent, accurate, timely, state-of-the-art, with some indication of an associated level of uncertainty. FY 2000 is the last year of the three year lifecycle of the project which was chosen to parallel FEMA 's development of a wind module to their HAZUS GIS software. Matching funds for FY 1998 and 1999 were committed after the PI made a formal presentation of the HPCC proposal to the panel of wind experts chosen to guide the HAZUS wind module effort by FEMA and the National Institute for Building Sciences (NIBS). When completed, HAZUS will be freely distributed to state and local emergency managers. Tropical cyclone analysis system products derived from real-time and archived wind fields will be designed for input to HAZUS. The wind module of HAZUS will allow storm information to be combined with geographic and demographic databases to produce specialized loss assessment maps for recovery management and the formulation of mitigation strategies. These uses of storm information are consistent with the findings of the World Disasters Report 1999 issued by the International Federation of Red Cross and Red Crescent Societies (EOS 1999), the National Science and Technology Council symposium "Real-time Monitoring and Warning for Natural Hazards" (EOS 1998), a recent National Academy of Sciences (1996) report, "Computing and Communications in the Extreme" which identified challenges confronting crisis managers, including: 1) "need for cooperation among many different actors", 2) "need to rapidly identify, collect, and integrate crucial information about the developing situation", and 3) "capability to make projections and initiate actions in the face of an inevitable degree of uncertainty and incompleteness of information".

3. Proposed Solution

We propose a real-time system for examining, synthesizing and objectively analyzing meteorological observations in hurricanes, using a common framework for wind exposure, measurement height, and averaging time. This system, called "H*WIND", will allow scientists to interact with the observations, perform quality control, and select from a menu of several graphical products depicting meteorological fields for storm diagnosis and forecast guidance. The HRD approach to hurricane wind analysis has evolved from a series of peer-reviewed, scientific publications analyzing landfalls of major hurricanes from 1979-1998 (Powell and Houston, 1996, 1998, Powell et al., 1998). Since 1994, HRD wind analyses have been conducted on an experimental basis to create real time hurricane wind field guidance for forecasters at the National Hurricane Center. These analyses are placed on the web after 24 h (www.aoml.noaa.gov/hrd see storm atlas) and have become the standard for assessing winds from new remote sensing platforms (e.g. RADARSAT, QUIKSAT) and parametric wind models used by the insurance industry. In addition we have had discussions with other operational and research organizations about using HRD wind fields on an experimental basis for initializing some numerical forecast models and to provide forcing for storm surge prediction models.

For prelandfall cases, the proposed system would create products designed to be useful for disaster planning. For example, wind analyses could be combined with the track forecast and error statistics to project "swath" fields depicting potential damage along an envelope of possible storm tracks. For hurricane landfall cases, the system would provide a menu of products designed specifically for real-time emergency management damage assessment applications. These fields will be formatted to be readily input to GIS and damage modeling software such as FEMA's HAZUS.

All available wind measurements gathered by reconnaissance aircraft, satellite remote sensors, airborne Doppler radar, ships, buoys, coastal and inland automatic weather stations will be automatically downloaded, preprocessed, and stored using a modern object-relational database located on a dedicated server. One or more additional machines will be dedicated as an objective analysis server and an application server. The application server will use distributed object technology to communicate actions and events between the clients and the database and analysis servers. All data and analyses will be archived on the database server and JAVA applets and IDL will allow graphical and gridded products to be created dynamically from the analysis archive and delivered to the client "on the fly". Scientific users would interact with the data and archive through a hardware-independent Web browser client or by a JAVA workstation client. Emergency managers would interact with current products based on operational or poststorm analyses through a Web interface. For scenario studies, users could construct products searching the archive by year, storm name, storm category, or geographic area.

a. Object-Oriented Approach

Object-orientation benefits entire projects, not just individual subsystems through code reuse, use of design patterns, rapid-development, more accurate resource estimation and more effective and efficient testing and maintenance. In light of these benefits and because vocabulary, notation and strategies are easily shared throughout an object oriented project, this project and its subprojects will use an OO iterative development method from beginning to end. The project has three basic subsystems: 1) Quality Control, 2) Analysis Automation, and 3) Output Generation (Powell et al. 1998). A graphically-oriented Quality Control (QCClient) subsystem session involves selecting desired observation types to be viewed, and determining a storm-track-based time window for viewing the data. Decisions are made about data validity through visual nearest-neighbor comparison and inspection. Data are then passed through a series of Analysis Automation subsystem components which are stand-alone programs distributed to allow access from different client machines. All steps in the analysis process are archived in a modern off-the shelf database management system. The Output Generation Subsystem creates graphical representations of various wind field based products via calls to off-the shelf data visualization software.

b. Database dependence

The database approach to data archival provides several advantages over traditional file processing approaches. Among these are: 1) self description (a database's ability to not only contain data but to contain a description of itself), 2) insulation between programs and data, 3) data abstraction (users are not required to understand the internal data structures or the methods that manipulate them), 4) support of multiple views of the same data, and 5) sharing of data and multi-user transaction processing. Furthermore, a good database system automatically solves many of the problems inherent in most data processing projects such as controlling redundancy, restricting unauthorized access, providing for persistent storage of program objects and data structures, representing complex relationships among data, and enforcing integrity constraints for the data (Elmasri and Navathe, 1994). Object-relational databases combine both philosophies (OO and relational) and tend to represent not only the best qualities of OO databases, but also those of relational databases, namely superior storage algorithms (please refer to http://www.storm.aoml.noaa.gov for further details on the Database Evaluation).

c. Platform independence

The JAVA programming language was chosen because its write once, run code for a wide variety of computing platforms. With JAVA, the proposed application, or suite of applications, needs to be written only once and run either as a JAVA application when running the workstation version or as a JAVA applet embedded in HTML for the web version. Platform independent code coupled with web deployment will allow users to not only use any machine they want (as long as it supports the JAVA virtual machine), but also to be wherever they want on the Internet

d. Distributed Objects

For computational load sharing, we are using a distributed OO system over several distinct application, analysis, and data servers. Distributed object (DO) technology will provide an immediate solution in the area of analysis automation. The current objective analysis software, written in FORTRAN 77, will be wrapped in C and transparently invoked by a Java client using Java Native Interface (JNI) or any CORBA client. Object distribution aspects of the project are the subjects of a Masters Thesis in Computer Science at Florida International University.

e. Evaluation

Incremental improvements and evaluation of the developing system software are conducted each hurricane season in conjunction with the HRD annual field program. During Hurricane landfall episodes, HRD scientists work side by side hurricane specialists at NHC using the current version of the analysis system to perform wind analyses on a regular 3 or 6 hour schedule consistent with NHC's warning and forecast cycle. The evaluation program has resulted in useful wind field guidance for NHC, valuable interactions between HRD research scientists and NHC operational forecasters, and worthwhile feedback for improving the wind analysis system.

f. Maintenance, Deployment, and Distribution Issues

The interactive workstation/web version of H*WIND will be coded and maintained by HRD and evaluated at NHC and AOML. This version may be deployed or made available within NHC and AOML to hurricane specialists and scientific staff as a local research application. Most landfall products and archival products from past storms would be derived from the interactive version. HRD will maintain a database archive of past storms and make this information dynamically available over the Web. Although initially an automated operational version of the analysis system was envisioned, currently there is insufficient programming staff at NHC to work on developing an operational (NHC maintained) version of the code. HRD will focus resources on developing H*WIND as an interactive workstation / web application to support HRD's real time wind analyses and to provide post landfall information derived from HRD analyses to emergency managers. Since H*WIND is a JAVA application, HRD will deploy, maintain, and update the software from our web site at AOML. No NHC hardware, software, or programming resources are requested for development or deployment of H*WIND. Upon completion of the Beta version of the software (June 2000), for our final evaluation period during the hurricane season, we will describe H*WIND at an NHC seminar and offer its use as a research tool for interested NHC staff. H*WIND should be especially helpful in assisting hurricane specialists preparing preliminary reports. HRD will provide any training required to bring users up to speed and H*WIND will come with a tutorial and online help to allow any scientist to become proficient without special training. Feedback from NHC users of the software will be incorporated into the final version.

g. NHC Involvement

At this point the H*WIND software is considered a local research tool to support HRD's real-time wind analysis research and to provide postlandfall information to the emergency management community. HRD works very closely with NHC during the hurricane season as a part of our annual field program and maintains several workstations in HRD offices located there. HRD's real-time wind analyses are considered to be experimental products that are provided as guidance to NHC forecasters. Each hurricane season, HRD expends as many as 500 person hours with scientists working shifts to create and evaluate real-time wind analyses. Feedback from NHC and other users helps to improve the product for the subsequent year. Our experience over the past three hurricane seasons suggests that the analyses are valuable to the forecasters, especially for identifying the wind radii to be used in advisories. This proposal enlists Dr. Ed Rappaport, chief of NHC's Technical Support Branch, to provide advice in the design of graphical wind field products (derived from the HRD analyses) to assist the emergency management community. A small amount of his time (perhaps 5h in total) will be requested to attend 2-3 informal meetings during FY 2000 with the HRD PI and with potential emergency management users of products. NHC, HRD, and FEMA would discuss dissemination and delivery of archived and real-time products including product design and content, uncertainty depiction, information security, and digital format for incorporation to GIS.

Long term (3-5 years), it is possible that an automated version of the analysis software could be constructed for possible use in operations. We may investigate creating an automated version of the system in cooperation with NHC at a later date. Conceptually, this type of tool should be considered a local application to supplement what is already available through N-AWIPS. It would contain design elements that are most useful for tropical cyclones, but since it is easily portable it could become an important tool for international tropical cyclone warning efforts, especially as new remote sensing systems come online. Proponents of the upcoming World Weather Research Program endorsed by the

WMO have discussed including H*WIND as a forecast demonstation project.

4. Milestones and Deliverables

FY-1999* Milestones, Deliverables, and Progress Report (a more detailed progress report is available at www.storm.aoml.noaa.gov)

1. 10-01-1999 Completion of scripts for automated data transfer from space-, aircraft-, ocean-, and land-based observing systems using Local Data Manager (LDM).

2. 07-15-1999 Prototype database schema design and evaluation versions of the database.

3. 11-01-1999 Continue development of graphical, interactive, workstation/web version of analysis software (H*WIND).

4. 12-01-1999 Design of operational, research, and Emergency Management (EM) products.

5. 09-15-1999 Evaluation of Java-based workstation/web (alpha) version of analysis at NHC, AOML.

* The project commenced when the HPCC funds were received in January 1999.

FY-1999 Deliverables: Automated LDM-based data acquisition system. Prototype database for H*WIND development. Evaluation version of H*WIND for testing during 1999 season. Meeting to design graphical EM wind products. Static Web delivery of graphical wind products for EM use.

b. FY-2000 Milestones

2-2000 Implementation of database to analysis system

4-2000 Integration of distributed objects, database server, analysis server, and application server to analysis system including security and product validity

6-2000 Web interface to archive of analyses including EM product menu

Summer-2000 Final release of interactive version of analysis system including web interface and web access to storm wind field information

FY-2000 Deliverables: Dynamic Web access to archival and real-time wind products, Hardware independent Java application and Web front-end for conducting data examination and analysis, paper describing system for IEEE journal.

5. Budget

The project is currently on budget. Matching funding from the National Institute for Building Science will arrive after AOML and ERL finance work out details for invoicing NIBS. An important issue has arisen regarding the minimal concurrent user licence configuration and software requirements for the Oracle 8i object-relational database. These requirements and the cost of the required software have increased by a factor of five since we first submitted our proposal for FY-1998. We are funding the software by leveraging this project with resources from other programs including recently submitted or already funded proposals to ESDIM, USWRP, base funding, and the private sector.

FY-2000 Budget: A Distributed, Real-time Hurricane Wind Analysis System				
Category	**Description**	**FY1998**	**FY1999**	**FY2000**
Personnel	CIMAS Research Associate, Student Programmer	144	144	144
Travel/Transportation	for conferences, meetings	6	6	6
Totals	.	150	150	150

HRD/NHC Contributions:

Personnel Labor: Principal investigators (HRD, NHC), applied mathematician (HRD)

Capitol Costs (HRD/AOML): Developer workstations, software, hardware, training, Internet and intranet access. Research observations gathered by NOAA P-3 and G-IV aircraft in offshore and landfalling storms through the HRD annual field program including the Winds at Landfall experiment. C-MAN station enhancement and ASOS station wind exposure documentation required to correct inland wind observations in hurricanes (supported by HRD funding through the U.S. Weather Research Program).

6. Project-related References

Amat, L., M. D. Powell, S. H. Houston, and N.Morisseau-Leroy, 1998: WANDA: HRD's Real-time Tropical Cyclone Wind Analysis Distributed Application. 14th Conf. on Interactive Information and Processing Systems, Phoenix, AZ., 11-16 Jan, Amer. Meteor. Soc.

Burpee, R. W., S. D. Aberson, P. G. Black, M. DeMaria, J. L. Franklin, J. S. Griffin, S. H. Houston, J. Kaplan, S. J. Lord, F. D. Marks, Jr., M. D. Powell, and H. E. Willoughby, 1994: Real-time guidance provided by NOAA's Hurricane Research Division to forecasters during Emily of 1993. **Bull. Amer. Meteor. Soc.**, 75, 1765-1783.

Elmasri, R. and S. Navathe, 1994: *Fundamentals of Database Systems*, Benjamin-Cummings, Redwood City, CA, 4-15.

EOS, 1998: Real-time monitoring and warning for natural hazards can provide real-time benefits. AGU Transactions, p.329.

EOS, 1999: Report warns of more natural disasters. AGU Transactions, 317-319.

Griffin, J.S., R. W. Burpee, F. D. Marks, Jr., and J. L. Franklin, 1992: Real-time airborne analysis of aircraft data supporting operational hurricane forecasting. **Wea. Forecasting**, 7, 480-490.

Jacobson, I., M.Christerson, P. Jonsson and G. Overgaard, 1992: Object Oriented Software Engineering: A Use Case Driven Approach, Addison-Wesley, Reading, MA, 271pp.

Morisseau-Leroy, N., 1997: Atmospheric Observations, Analyses, and The World Wide Web Using a Semantic Database, Master Thesis, School of Computer Sciences, Florida International University, Miami, Florida.

Morisseau-Leroy, N., 1998: A Semantic Data Model For Atmospheric Observations, Storm Track Data, and Wind Analyses. 14th Conf. on Interactive Information and Processing Systems, Phoenix, AZ., 11-16 Jan, Amer. Meteor. Soc.

National Research Council, 1996: Computing and Communications in the Extreme.

Powell, M. D., S. H. Houston, and I. Ares, 1995: Real-time damage assessment in hurricanes. 21st AMS Conference on hurricanes and tropical meteorology, Miami, FL., April 24-28, 1995, p 500-502.

Powell, M. D., S. H. Houston, and T. A. Reinhold, 1996: Hurricane Andrew's landfall in South Florida. Part I: Standardizing measurements for documentation of surface wind fields. **Wea. Forecasting**, 11, 304-328.

Powell, M. D., and S. H. Houston, 1996: Hurricane Andrew's landfall in South FLorida. Part II: Surface wind fields and potential real-time applications. **Wea. Forecasting**, 11, 329-349.

Powell, M. D., and S. H. Houston, 1996: Hurricane Andrew's landfall in South Florida. Part II: Surface wind fields and potential real-time applications. Wea. Forecasting, 11, 329-349.

Powell, M. D., S. H. Houston, L. R. Amat, and N. Morisseau-Leroy, 1997: The HRD hurricane wind analysis system. 8th U.S. National Conference on Wind Engineering, Baltimore, MD., June 5-7, 1997. Also to appear in **J. Wind Engineering and Indust. Aerodynamics** (in press).

Powell, M. D., and S. H. Houston, 1997: Surface Wind Fields of 1995 Hurricanes Erin, Opal, Luis, Marilyn, and Roxanne at Landfall, **Mon. Wea. Rev**., in press.

Yourdon, E., 1994: Object Oriented Systems Design: An Integrated Approach, Yourdon Press, Englewood Cliffs, NJ, 288pp.